NASA/TM—2000–209891, Vol. 50

Te Report Se on the
B osystem-A sphere Study (BOREAS)

ll and Jaime Nickeson, Editors

50

AS RSS-4 1994 Jack Pine Leaf
lodeled Spectra in

, N. Lucas, and T. Dawson

nautics and
stration

ce Flight Center
ryland 20771

July

The NASA STI Program Office ... in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

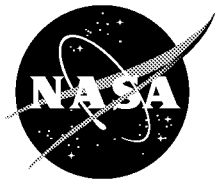
- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.
- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.
- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and mission, often concerned with subjects having substantial public interest.
- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at http://www.sti.nasa.gov/STI-homepage.html
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA Access Help Desk at (301) 621-0134
- Telephone the NASA Access Help Desk at (301) 621-0390
- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076-1320

NASA/TM—2000–209891, Vol. 50



Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall and Jaime Nickeson, Editors

Volume 50

BOREAS RSS-4 1994 Jack Pine Leaf Biochemistry and Modeled Spectra in the SSA

Stephen Plummer, Institute of Terrestrial Ecology, UK
Neil Lucas, University of Kingston, UK
Terry Dawson, University of Southampton, UK

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

July 2000

Available from:

NASA Center for AeroSpace Information
7121 Standard Drive
Hanover, MD 21076-1320
Price Code: A17

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Price Code: A10

BOREAS RSS-4 1994 Jack Pine Leaf Biochemistry and Modeled Spectra in the SSA

Stephen Plummer, Neil Lucas, Terry Dawson

Summary

The BOREAS RSS-4 team focused its efforts on deriving estimates of LAI and leaf chlorophyll and nitrogen concentrations from remotely sensed data for input into the Forest BGC model. This data set contains measurements of jack pine (Pinus banksiana) needle biochemistry from the BOREAS SSA in July and August 1994. The data contain measurements of current and year-1 needle chlorophyll, nitrogen, lignin, cellulose, and water content for the OJP flux tower and nearby auxiliary sites.

The data have been used to test a needle reflectance and transmittance model, LIBERTY (Dawson et al., in press). The source code for the model and modeled needle spectra for each of the sampled tower and auxiliary sites are provided as part of this data set. The LIBERTY model was developed and the predicted spectral data generated to parameterize a canopy reflectance model (North, 1996) for comparison with AVIRIS, POLDER, and PARABOLA data. The data and model source code are stored in ASCII files.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS RSS-04 1994 Jack Pine Leaf Biochemistry and Modeled Spectra in the SSA

1.2 Data Set Introduction

The needle biochemistry data set described here was obtained from the Southern Study Area (SSA) Old Jack Pine (OJP) (Pinus banksiana) site during Intensive Field Campaign (IFC)-2 in 1994 (19-Jul to 08-Aug-1994) of the BOReal Ecosystem-Atmosphere Study (BOREAS). The data were collected to help parameterize leaf and canopy reflectance and ecosystem simulation models. The data comprise

measurements of current and year 1 needle chlorophyll, nitrogen, lignin, cellulose, and water content for tower and auxiliary sites located around the OJP flux tower. The needles were stripped from branches sampled from the upper canopy using a shotgun or, where the canopy was low, using clippers. Also included as part of this data set are the source code for the Leaf Incorporating Biochemistry Exhibiting Reflectance and Transmittance Yields (LIBERTY) model and modeled needle spectra for each of the sampled tower and auxiliary sites. The data set also contains needle spectral reflectance and transmittance for these samples generated using the LIBERTY model. LIBERTY is a leaf reflectance model developed as part of a doctoral thesis by Terry Dawson; a full description is available from references given in Section 17. A copy of the source code for version 1.1 of the software is available on request. See Section 14.2.

1.3 Objective/Purpose

The Remote Sensing Science (RSS)-04 investigations were designed to obtain Leaf Area Index (LAI), fraction of absorbed Photosynthetically Active Radiation fPAR and foliar chemistry data for a complex, spatially variable forest canopy in order to:

- Parameterize an ecosystem simulation model.
- Test empirical relationships hypothesized between biophysical variables and remotely sensed data.
- Parameterize a forest reflectance model and compare it with Airborne Visible and Infrared Imaging Spectrometer (AVIRIS), Polarization and Directionality of Earth Reflectance (POLDER) and Portable Apparatus for Rapid Acquisitions of Bidirectional Observations of Land and Atmosphere (PARABOLA) data to deduce whether observed between canopy chemistry and reflectance are a product of canopy structure rather than foliar chemical variations themselves (see reference list, Section 17).
- Drive the ecosystem simulation model with estimates of LAI and chemistry derived from remotely sensed data.

1.4 Summary of Parameters

Variation in jack pine needle chemistry comprising: cellulose, chlorophyll, lignin, nitrogen, and water across the range (high, medium, low production) of auxiliary and tower sites. Needle reflectance and transmittance spectra were generated using the LIBERTY needle reflectance model (see references).

1.5 Discussion

The measurements that comprise this data set were collected as a contribution to the determination of the biochemical characteristics of the BOREAS SSA. Such measurements were required to parameterize leaf and canopy reflectance models and as initial indicators of canopy state for use in ecosystem models such as FOREST-BGC. The data set provided here is curently experimental, for reasons described below and should be used in this context.

1.6 Related Data Sets

BOREAS RSS-04 1994 Southern Study Area Jack Pine LAI and FPAR Data
BOREAS RSS-07 LAI, Gap Fraction, and fPAR Data
BOREAS TE-09 Photosynthetic Capacity and Foliage Nitrogen Data over the NSA

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Stephen Plummer, Professor Paul Curran

2.2 Title of Investigation

RSS-04: Coupling Remotely Sensed Data to Ecosystem Simulation Models

2.3 Contact Information

Contact 1:
Dr. Stephen Plummer
Role: data collection and transport, project supervision
Section for Earth Observation
Institute of Terrestrial Ecology
Monks Wood
Abbots Ripton
Cambs, PE17 2LS UK
+44 1487 773381
+44 1487 773277 (fax)
S.Plummer@ite.ac.uk

*formerly Remote Sensing Applications Development Unit British National Space Centre

Contact 2:
Dr. Neil Lucas
Role: data collection and transport
School of Geography
University of Kingston
Penrhyn Road
Kingston upon Thames
Surrey, KTI 2EE UK
+44 181 547 7510
+44 181 547 7497 (fax)

Contact 3:
Mr. Terry Dawson
Role: sample processing and the LIBERTY model
Doctoral student
Department of Geography
University of Southampton
Highfields
Southampton, SO17 1BJ UK

Contact 4:
Jaime Nickeson
Raytheon ITSS
NASA GSFC
Code 923
Greenbelt, MD 20771
(301) 286-3373
(301) 286-0239 (fax)
Jaime.Nickeson@gsfc.nasa.gov

3. Theory of Measurements

For discussion of the LIBERTY leaf reflectance model, please see the papers by Dawson et al.

4. Equipment

4.1 Sensor/Instrument Description

4.1.1 Collection Environment

Branch samples were collected in ambient atmospheric conditions during the sampling period.

4.1.2 Source/Platform

All spectral measurements were made using laboratory facilities at the Universities of Southampton and New Hampshire.

4.1.3 Source/Platform Mission Objectives

Not applicable.

4.1.4 Key Variables

Concentrations (mass basis) of cellulose, chlorophyll, lignin, nitrogen, and water in current and >= 1-year-old needles. Infinite reflectance, single needle reflectance, and transmittance predicted using the LIBERTY needle reflectance model (see references).

4.1.5 Principles of Operation

A Perkin-Elmer Lambda 19 spectrophotometer was used for 'infinite reflectance' measurements of fresh and dried ground jack pine needles as well as powdered samples of individual biochemicals. Infinite reflectance is the reflectance from a stack of needles of sufficient thickness that the addition of more needles does not change the reflectance.

The Perkin-Elmer Lambda 19 spectrophotometer is a double-beam, double-monochromator, ratio recording spectrometer operating in the ultraviolet, visible, and near-infrared spectral ranges. The instrument was connected to an integrating sphere 60 mm in diameter. The two detectors consisted of (i) a side window photomultiplier for the visible wavelengths and (ii) a PbS detector for the near-infrared wavelengths. A prealigned tungsten-halogen lamp provided the illumination source. The reflectance spectra of samples were scanned over the 400-2500-nm wavelength interval with 1-nm increments. The spectral resolution varied between 1 to 2 nm in the 400-1000 nm wavelengths and from 4 to 5 nm in the middle infrared (1000-2500 nm). Calibration of the instrument was performed using internal radiometric and spectral calibration standards and a barium sulphate ($BaSO_4$) standard. Instrumental corrections were performed as necessary, according to sample mounting and measurement type (Hosgood et al., 1994). Because water vapor absorbs radiation in the near-infrared range, the instrument was continually purged with nitrogen during measurements, the pressure being maintained at 3 to 4 bars.

Measurements of single jack pine needle reflectance and transmittance spectra were made using a Zeiss Universal Microspectrophotometer (UMSP) 50 microscope that was linked to a computer for data acquisition and processing. Illumination was from a 100 W tungsten light with a color temperature of 3400 K. Depending upon the optical configuration, reflectance and transmittance measurements were taken at 1 nm steps over a wavelength range of 400-800 nm, individual values being determined from a mean of 16 measurements taken along the length of each needle and based upon a mean of 10 measurements taken at each sample point. A grating monochromator was used between the leaf specimen and the photometer with a slit width set to 10 nm. Measurements were made under an X20 dry objective with a measurement spot of approximately 500 micrometers being used, although this was varied to the largest possible area measurement of the leaf surface to maintain maximum homogeneity. Measurements were standardized against a didymium spectroscopy standard.

Leaf biochemistry measurements were generated from needle samples obtained at 10 jack pine tower/auxiliary sites located in the vicinity of the SSA OJP and Young Jack Pine (YJP) Tower sites. Eight branch samples per site were obtained after sundown. The branchlets were immediately divided into current year and greater than 1-year-old needles and stored in polythene bags in cold boxes. The samples were then transferred to refrigerators at Paddockwood School. The branchlet samples were stripped of their needles and the needles weighed before transfer to a freezer to await shipping back to the UK.

4.1.6 Sensor/Instrument Measurement Geometry

See Sections 4.1.1 and 4.1.5.

4.1.7 Manufacturer of Sensor/Instrument**

Perkin-Elmer Analytical Instruments
Seer Green Customer Centre
Chalfont Rd, Seer Green
Bucks HP9 2FX, UK
(http://www.perkin-elmer.com/)

Carl Zeiss Ltd
P.O. Box 78
Woodfield Rd
Welwyn Garden City
Herts AL7 1L, UK
(http://www.zeiss.co.uk/)

** Mention of company names or instruments does not indicate recommendation by the Natural Environment Research Council (NERC) or the University of Southampton.

4.2 Calibration

Prediction of chemistry is dependent on known calibration standards provided by (for chlorophyll) the Aldrich Chemical Company (UK) and (for lignin, cellulose and nitrogen) developed by the University of New Hampshire (UNH).

LIBERTY was developed specifically for conifer needles so the estimation of single leaf reflectance and transmittance spectra from stacked needles is possible. However, the program is equally valid for any leaf species with the minor caveat that the in-vivo absorption coefficients used were determined from empirical work on various pine species.

4.2.1 Specifications

Calibration of the Perkin-Elmer instrument was performed using internal radiometric and spectral calibration standards and a BaSO4 standard. Instrumental corrections were performed as necessary, according to sample mounting and measurement type (Hosgood et al., 1994). Because water vapor absorbs radiation in the near-infrared range, the instrument was continually purged with nitrogen during measurements, the pressure being maintained at 3 to 4 bars. Measurements with the Zeiss instrument were standardized against a didymium spectroscopy standard.

4.2.1.1 Tolerance

None given.

4.2.2 Frequency of Calibration

None given.

4.2.3 Other Calibration Information

Not applicable.

5. Data Acquisition Methods

These leaf biochemistry measurements were generated from needle samples obtained at 10 jack pine tower/auxiliary sites located in the vicinity of the SSA OJP and YJP tower sites. The site codes are as follows:

F5I6P*
F7J0P
F7J1P
F8L6T (SSA-YJP tower)
G1K9P
G2L3T (SSA-OJP tower)
G4K8P
G7K8P
G8L6P
G9L0P

*See Section 6.2, Field Notes.

Samples were acquired from the upper tree canopy using either tree clippers (for young trees) or a large-bore shotgun for mature trees.

Shotgun sampling was restricted to areas outside the wind aligned blob (WAB) for the two tower sites. Shotgun sampling in the upper canopy is more difficult than it seems, primarily because the shooting position can result in shoulder bruising from the recoil and because of the resistance of branches to falling. A number of shot types were assessed in the sampling and the most effective type for bringing down branches from the upper canopy proved to be 00 gauge, a compromise between large scatter and high velocity shot.

Eight branch samples per site were obtained after sundown. The branchlets were immediately divided into current year and greater than 1-year-old needles and stored in polythene bags in cold boxes. The samples were then transferred to refrigerators at Paddockwood School. The branchlet samples were stripped of their needles and the needles weighed before transfer to a freezer to await shipping back to the UK.

For shipping, the samples were sealed in polythene Ziploc bags in a cool box containing dry ice. Because of Federal Aviation Administration (FAA) regulations on transport of dry ice on passenger aircraft, the amount of dry ice used was restricted. On arrival in the UK, the samples were transferred to a large freezer facility at University of Wales, Swansea, and subsequently to a similar facility at the University of Southampton.

6. Observations

6.1 Data Notes

None given.

6.2 Field Notes

02-Aug-1995 Site F5I6P not found. A sample site was thus established at 150 m in from Route 913 on a bearing of 59 degrees.

- 02-Aug-1995 Site F7J1P 60% Jack Pine, 20% Spruce, 20% Aspen.
- 02-Aug-1995 Site F7J0P 34% Jack Pine, 33% Spruce, 33% Aspen.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

The eight branch samples per site were a compromise between time/manpower and representativeness, particularly given that some of the auxiliary sites were not particularly uniform in terms of species. The coverage was also restricted to jack pine for the same reasons. The following site locations were sampled North American Datum of 1983 (NAD83):

Site	West Longitude	North Latitude	UTM Easting	UTM Northing	UTM Zone
F8L6T	104.64527	53.87581	523350.7	5969540.0	13
G2L3T	104.69203	53.91634	520257.0	5974035.0	13
F5I6P	105.11174	53.86608	492681.9	5968405.0	13
F7J0P	105.05116	53.88334	496666.7	5970320.0	13
F7J1P	105.03226	53.88211	497909.2	5970183.0	13
G1K9P	104.74810	53.90881	516576.8	5973183.0	13
G4K8P	104.76399	53.91884	515529.6	5974295.0	13
G7K8P	104.77147	53.95882	515023.9	5978742.0	13
G8L6P	104.63755	53.96558	523807.6	5979530.0	13
G9L0P	104.73778	53.97576	517227.6	5980634.0	13

7.1.2 Spatial Coverage Map

Not available.

7.1.3 Spatial Resolution

The data are point measurements at the given locations.

7.1.4 Projection

Not applicable.

7.1.5 Grid Description

Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

All the samples were collected from 25-Jul-1994 to 05-Aug-1994.

7.2.2 Temporal Coverage Map

Not available.

7.2.3 Temporal Resolution

These data represent the jack pine leaf chemistry during the 1994 growing season.

7.3 Data Characteristics

7.3.1 Parameter/Variable

Model Data: Infinite reflectance, single needle reflectance and transmittance predicted using the LIBERTY needle reflectance model (see refs). The parameters contained in the data files on the CD-ROM are:

For sample data:

```
         Column Name
------------------------------
SITE_NAME
SUB_SITE
START_DATE
END_DATE
OP_GRID_ID
SAMPLE_NUM
SAMPLE_GROUP
LEAF_WATER_CONC
LEAF_NITROGEN_CONC
LEAF_LIGNIN_CONC
LEAF_CELLULOSE_CONC
LEAF_CHLOROPHYL_A_CONC
LEAF_CHLOROPHYL_B_CONC
LEAF_CHLOROPHYL_TOT_CONC
REVISION_DATE
CRTFCN_CODE
```

For mean data:

```
         Column Name
------------------------------
SITE_NAME
SUB_SITE
START_DATE
END_DATE
OP_GRID_ID
SAMPLE_GROUP
NUM_OBS
MEAN_LEAF_WATER_CONC
SDEV_LEAF_WATER_CONC
MEAN_LEAF_NITROGEN_CONC
SDEV_LEAF_NITROGEN_CONC
MEAN_LEAF_LIGNIN_CONC
SDEV_LEAF_LIGNIN_CONC
MEAN_LEAF_CELLULOSE_CONC
SDEV_LEAF_CELLULOSE_CONC
MEAN_LEAF_CHLOROPHYL_A_CONC
SDEV_LEAF_CHLOROPHYL_A_CONC
MEAN_LEAF_CHLOROPHYL_B_CONC
SDEV_LEAF_CHLOROPHYL_B_CONC
MEAN_LEAF_CHLOROPHYL_TOT_CONC
SDEV_LEAF_CHLOROPHYL_TOT_CONC
REVISION_DATE
CRTFCN_CODE
```

7.3.2 Variable Description/Definition

The descriptions of the parameters contained in the data files on the CD-ROM are:

Model data:

Variable	Definition
infinite reflectance	predicted reflectance
single needle reflectance	predicted single needle reflectance
transmittance	predicted single needle transmittance

For sample data:

Column Name	Description
SITE_NAME	The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, TRN, and TTT identifies the cover type for the site, 999 if unknown, and CCCCC is the identifier for site, exactly what it means will vary with site type.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
START_DATE	The date on which the collection of data commenced.
END_DATE	The date on which the collection of the data was terminated.
OP_GRID_ID	The identifier given to the BOREAS auxiliary and tower sites during the execution of field operations. An example of this is B9B7A.
SAMPLE_NUM	The number of the sample.
SAMPLE_GROUP	Arbitrary designation assigned to a group of samples which were used to derive statistics.
LEAF_WATER_CONC	Water content, calculated as a function of dry mass, in current and >= 1-year-old needles.
LEAF_NITROGEN_CONC	Spectrally-derived concentration of cellulose in current and >= 1-year-old needles.
LEAF_LIGNIN_CONC	Spectrally-derived concentration of lignin in current and >= 1-year-old needles.
LEAF_CELLULOSE_CONC	Spectrally-derived concentration of cellulose in >= 1-year-old needles
LEAF_CHLOROPHYL_A_CONC	Spectrophotometrically derived concentration of chlorophyll-a in current and >= 1-year-old needles
LEAF_CHLOROPHYL_B_CONC	Spectrophotometrically derived concentration of chlorophyll-b in current and >= 1-year-old needles
LEAF_CHLOROPHYL_TOT_CONC	Spectrophotometrically derived concentration of total chlorophyll in current and >= 1-year-old needles
CRTFCN_CODE	The BOREAS certification level of the data.

	Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI but questionable).
REVISION_DATE	The most recent date when the information in the referenced data base table record was revised.

For mean data:

Column Name	Description
SITE_NAME	The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, TRN, and TTT identifies the cover type for the site, 999 if unknown, and CCCCC is the identifier for site, exactly what it means will vary with site type.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
START_DATE	The date on which the collection of data commenced.
END_DATE	The date on which the collection of the data was terminated.
OP_GRID_ID	The identifier given to the BOREAS auxiliary and tower sites during the execution of field operations. An example of this is B9B7A.
SAMPLE_GROUP	Arbitrary designation assigned to a group of samples which were used to derive statistics.
NUM_OBS	Number of observations of the given sample used to calculate given values.
MEAN_LEAF_WATER_CONC	Mean leaf water content, calculated as a function of dry mass, in current and >= 1-year-old needles.
SDEV_LEAF_WATER_CONC	Standard deviation of leaf water content, calculated as a function of dry mass, in current and >= 1-year-old needles.
MEAN_LEAF_NITROGEN_CONC	Mean spectrally-derived concentration of nitrogen in current and >= 1-year-old needles.
SDEV_LEAF_NITROGEN_CONC	Standard deviation of spectrally-derived concentration of nitrogen in current and >= 1-year-old needles.
MEAN_LEAF_LIGNIN_CONC	Mean of spectrally-derived concentration of lign in in current and >= 1-year-old needles.
SDEV_LEAF_LIGNIN_CONC	Standard deviation of spectrally-derived concentration of lignin in current and >= 1-year-old needles.
MEAN_LEAF_CELLULOSE_CONC	Mean spectrally-derived concentration of cellulose in current and >= 1-year-old needles.
SDEV_LEAF_CELLULOSE_CONC	Standard deviation of spectrally-derived concentration of cellulose in current and >= 1-year-old needles.

MEAN_LEAF_CHLOROPHYL_A_CONC	Mean of 8 samples of spectrophotometrically derived concentration of chlorophyll-a in current and >= 1-year-old needles
SDEV_LEAF_CHLOROPHYL_A_CONC	Standard deviation of spectrophotometrically derived concentration of chlorophyll-a in current and >= 1-year-old needles
MEAN_LEAF_CHLOROPHYL_B_CONC	Mean spectrophotometrically derived concentration of chlorophyll-b in current and >= 1-year-old needles
SDEV_LEAF_CHLOROPHYL_B_CONC	Standard deviation of spectrophotometrically derived concentration of chlorophyll-b in current and >= 1-year-old needles
MEAN_LEAF_CHLOROPHYL_TOT_CONC	Mean spectrophotometrically derived concentration of total chlorophyll in current and >= 1-year-old needles
SDEV_LEAF_CHLOROPHYL_TOT_CONC	Standard deviation of spectrophotometrically derived concentration of total chlorophyll in current and >= 1-year-old needles
CRTFCN_CODE	The BOREAS certification level of the data. Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI but questionable).
REVISION_DATE	The most recent date when the information in the referenced data base table record was revised.

7.3.3 Unit of Measurement

The measurement units for the parameters contained in the data files on the CD-ROM are:

Model data:

Variable	Units
infinite reflectance	unitless
single needle reflectance	unitless
transmittance	unitless

For sample data:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
START_DATE	[DD-MON-YY]
END_DATE	[DD-MON-YY]
OP_GRID_ID	[none]
SAMPLE_NUM	[none]
SAMPLE_GROUP	[none]
LEAF_WATER_CONC	[percent]
LEAF_NITROGEN_CONC	[percent]
LEAF_LIGNIN_CONC	[percent]
LEAF_CELLULOSE_CONC	[percent]
LEAF_CHLOROPHYL_A_CONC	[milligrams][gram^-1]
LEAF_CHLOROPHYL_B_CONC	[milligrams][gram^-1]
LEAF_CHLOROPHYL_TOT_CONC	[milligrams][gram^-1]
REVISION_DATE	[DD-MON-YY]
CRTFCN_CODE	[none]

For mean data:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
START_DATE	[DD-MON-YY]
END_DATE	[DD-MON-YY]
OP_GRID_ID	[none]
SAMPLE_GROUP	[none]
NUM_OBS	[counts]
MEAN_LEAF_WATER_CONC	[percent]
SDEV_LEAF_WATER_CONC	[percent]
MEAN_LEAF_NITROGEN_CONC	[percent]
SDEV_LEAF_NITROGEN_CONC	[percent]
MEAN_LEAF_LIGNIN_CONC	[percent]
SDEV_LEAF_LIGNIN_CONC	[percent]
MEAN_LEAF_CELLULOSE_CONC	[percent]
SDEV_LEAF_CELLULOSE_CONC	[percent]
MEAN_LEAF_CHLOROPHYL_A_CONC	[milligrams][gram^-1]
SDEV_LEAF_CHLOROPHYL_A_CONC	[milligrams][gram^-1]
MEAN_LEAF_CHLOROPHYL_B_CONC	[milligrams][gram^-1]
SDEV_LEAF_CHLOROPHYL_B_CONC	[milligrams][gram^-1]
MEAN_LEAF_CHLOROPHYL_TOT_CONC	[milligrams][gram^-1]
SDEV_LEAF_CHLOROPHYL_TOT_CONC	[milligrams][gram^-1]
REVISION_DATE	[DD-MON-YY]
CRTFCN_CODE	[none]

7.3.4 Data Source

The source of the parameter values contained in the data files on the CD-ROM are:

Model data:

Variable	Source
infinite reflectance	LIBERTY needle reflectance model
single needle reflectance	LIBERTY needle reflectance model
single needle transmittance	LIBERTY needle reflectance model

For sample data:

Column Name	Data Source
SITE_NAME	[Assigned by BORIS Staff]
SUB_SITE	[Assigned by BORIS Staff]
START_DATE	[RSS04 team]
END_DATE	[RSS04 team]
OP_GRID_ID	[RSS04 team]
SAMPLE_NUM	[RSS04 team]
SAMPLE_GROUP	[RSS04 team]
LEAF_WATER_CONC	[Laboratory analysis of fresh samples]
LEAF_NITROGEN_CONC	[Laboratory analysis of fresh samples]
LEAF_LIGNIN_CONC	[Laboratory analysis of fresh samples]
LEAF_CELLULOSE_CONC	[Laboratory analysis of fresh samples]
LEAF_CHLOROPHYL_A_CONC	[Laboratory analysis of fresh samples]
LEAF_CHLOROPHYL_B_CONC	[Laboratory analysis of fresh samples]
LEAF_CHLOROPHYL_TOT_CONC	[Laboratory analysis of fresh samples]

REVISION_DATE	[Assigned by BORIS Staff]
CRTFCN_CODE	[Assigned by BORIS Staff]

For mean data:

Column Name	Data Source
SITE_NAME	[Assigned by BORIS Staff]
SUB_SITE	[Assigned by BORIS Staff]
START_DATE	[RSS04 team]
END_DATE	[RSS04 team]
OP_GRID_ID	[RSS04 team]
SAMPLE_GROUP	[RSS04 team]
NUM_OBS	[RSS04 team]
MEAN_LEAF_WATER_CONC	[Laboratory analysis of fresh samples]
SDEV_LEAF_WATER_CONC	[Laboratory analysis of fresh samples]
MEAN_LEAF_NITROGEN_CONC	[Laboratory analysis of fresh samples]
SDEV_LEAF_NITROGEN_CONC	[Laboratory analysis of fresh samples]
MEAN_LEAF_LIGNIN_CONC	[Laboratory analysis of fresh samples]
SDEV_LEAF_LIGNIN_CONC	[Laboratory analysis of fresh samples]
MEAN_LEAF_CELLULOSE_CONC	[Laboratory analysis of fresh samples]
SDEV_LEAF_CELLULOSE_CONC	[Laboratory analysis of fresh samples]
MEAN_LEAF_CHLOROPHYL_A_CONC	[Laboratory analysis of fresh samples
SDEV_LEAF_CHLOROPHYL_A_CONC	[Laboratory analysis of fresh samples]
MEAN_LEAF_CHLOROPHYL_B_CONC	[Laboratory analysis of fresh samples]
SDEV_LEAF_CHLOROPHYL_B_CONC	[Laboratory analysis of fresh samples]
MEAN_LEAF_CHLOROPHYL_TOT_CONC	[Laboratory analysis of fresh samples]
SDEV_LEAF_CHLOROPHYL_TOT_CONC	[Laboratory analysis of fresh samples]
REVISION_DATE	[Assigned by BORIS Staff]
CRTFCN_CODE	[Assigned by BORIS Staff]

7.3.5 Data Range

The following table gives information about the parameter values found in the data files on the CD-ROM.

Model data:

Variable	Range
infinite reflectance	0.0 - 1.0
single needle reflectance	0.0 - 1.0
single needle transmittance	0.0 - 1.0

For sample data:

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	SSA-9JP-AUX02	SSA-YJP-FLXTR	None	None	None	None
SUB_SITE	RSS04-LCH01	RSS04-LCH01	None	None	None	None
START_DATE	25-JUL-94	25-JUL-94	None	None	None	None
END_DATE	05-AUG-94	05-AUG-94	None	None	None	None
OP_GRID_ID	F5I6P	G9L0P	None	None	None	None
SAMPLE_NUM	1	72	None	None	None	None
SAMPLE_GROUP	0	1	None	None	None	None
LEAF_WATER_CONC	55.6	164.9	-999	None	None	None

LEAF_NITROGEN_CONC	.8	1.51	None	None	None	None
LEAF_LIGNIN_CONC	21.98	28.23	None	None	None	None
LEAF_CELLULOSE_CONC	31.39	45.45	None	None	None	None
LEAF_CHLOROPHYL_A_CONC	.946	3.17	-999	None	None	None
LEAF_CHLOROPHYL_B_CONC	.056	1.129	-999	None	None	None
LEAF_CHLOROPHYL_TOT_CONC	1.278	4.001	-999	None	None	None
REVISION_DATE	26-AUG-98	26-AUG-98	None	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None

For mean data:

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	SSA-9JP-AUX02	SSA-YJP-FLXTR	None	None	None	None
SUB_SITE	RSS04-LCH01	RSS04-LCH01	None	None	None	None
START_DATE	25-JUL-94	25-JUL-94	None	None	None	None
END_DATE	05-AUG-94	05-AUG-94	None	None	None	None
OP_GRID_ID	F5I6P	G9L0P	None	None	None	None
SAMPLE_GROUP	0	1	None	None	None	None
NUM_OBS	6	11	None	None	None	None
MEAN_LEAF_WATER_CONC	72	146.6	-999	None	None	None
SDEV_LEAF_WATER_CONC	3.4	16.8	-999	None	None	None
MEAN_LEAF_NITROGEN_CONC	.975	1.285	-999	None	None	None
SDEV_LEAF_NITROGEN_CONC	.042	.142	-999	None	None	None
MEAN_LEAF_LIGNIN_CONC	23.373	27.298	-999	None	None	None
SDEV_LEAF_LIGNIN_CONC	.227	1.213	-999	None	None	None
MEAN_LEAF_CELLULOSE_CONC	33.616	43.565	-999	None	None	None
SDEV_LEAF_CELLULOSE_CONC	.453	2.386	-999	None	None	None
MEAN_LEAF_CHLOROPHYL_A_CONC	.294	.682	-999	None	None	None
SDEV_LEAF_CHLOROPHYL_A_CONC	.085	.212	-999	None	None	None
MEAN_LEAF_CHLOROPHYL_B_CONC	1.87	3.205	-999	None	None	None
SDEV_LEAF_CHLOROPHYL_B_CONC	.278	.644	-999	None	None	None
MEAN_LEAF_CHLOROPHYL_TOT_CONC	1.533	2.6	-999	None	None	None
SDEV_LEAF_CHLOROPHYL_TOT_CONC	.226	.565	-999	None	None	None
REVISION_DATE	26-AUG-98	26-AUG-98	None	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None

```
Minimum Data Value -- The minimum value found in the column.
Maximum Data Value -- The maximum value found in the column.
Missng Data Value  -- The value that indicates missing data. This is used to
                      indicate that an attempt was made to determine the
                      parameter value, but the attempt was unsuccessful.
Unrel Data Value   -- The value that indicates unreliable data.  This is used
                      to indicate an attempt was made to determine the
                      parameter value, but the value was deemed to be
                      unreliable by the analysis personnel.
Below Detect Limit -- The value that indicates parameter values below the
                      instruments detection limits.  This is used to
                      indicate that an attempt was made to determine the
                      parameter value, but the analysis personnel determined
                      that the parameter value was below the detection
                      limit of the instrumentation.
Data Not Cllctd    -- This value indicates that no attempt was made to
                      determine the parameter value.  This usually
                      indicates that BORIS combined several similar but
                      not identical data sets into the same data base table
                      but this particular science team did not
                      measure that parameter.

Blank -- Indicates that blank spaces are used to denote that type of value.
N/A   -- Indicates that the value is not applicable to the respective column.
None  -- Indicates that no values of that sort were found in the column.
--------------------------------------------------------------------------------
```

7.4 Sample Data Record

The following are wrapped verions of records from sample data files:

Model Predicted spectra file:

```
Wave,R,single refl,single trans,R,single refl,single trans,R,single refl,
single trans,R,single refl,single trans,R,single refl,single trans,R,
single refl,single trans,R,single refl,single trans,R,single refl,single trans,
R,single refl,single trans,R,single refl,single trans
400,0.026798,0.026788,0.019226,0.021052,0.021049,0.013404,0.022272,0.022268,
0.014603,0.023306,0.0233,0.015637,0.0226,0.022595,0.01493,0.026995,0.026984,
0.019432,0.026845,0.026835,0.019275,0.023424,0.023418,0.015756,0.020923,0.02092,
0.013278,0.023411,0.023405,0.015743
```

Sample data file:

```
SITE_NAME,SUB_SITE,START_DATE,END_DATE,OP_GRID_ID,SAMPLE_NUM,SAMPLE_GROUP,
LEAF_WATER_CONC,LEAF_NITROGEN_CONC,LEAF_LIGNIN_CONC,LEAF_CELLULOSE_CONC,
LEAF_CHLOROPHYL_A_CONC,LEAF_CHLOROPHYL_B_CONC,LEAF_CHLOROPHYL_TOT_CONC,
REVISION_DATE,CRTFCN_CODE
'SSA-9JP-AUX02','RSS04-LCH01',25-JUL-94,05-AUG-94,'F5I6P',1,'0',1.395,1.02,22.28,
41.92,1.303,.261,1.564,26-AUG-98,'CPI'
'SSA-9JP-AUX02','RSS04-LCH01',25-JUL-94,05-AUG-94,'F5I6P',2,'0',1.244,.88,22.28,
38.82,1.548,.259,1.807,26-AUG-98,'CPI'
'SSA-9JP-AUX02','RSS04-LCH01',25-JUL-94,05-AUG-94,'F5I6P',3,'0',1.25,.92,24.1,
39.1,1.101,.462,1.563,26-AUG-98,'CPI'
'SSA-9JP-AUX02','RSS04-LCH01',25-JUL-94,05-AUG-94,'F5I6P',4,'0',1.091,.92,23.17,
35.72,2.34,.28,2.621,26-AUG-98,'CPI'
```

Mean data file:

```
SITE_NAME,SUB_SITE,START_DATE,END_DATE,OP_GRID_ID,SAMPLE_GROUP,NUM_OBS,
MEAN_LEAF_WATER_CONC,SDEV_LEAF_WATER_CONC,MEAN_LEAF_NITROGEN_CONC,
SDEV_LEAF_NITROGEN_CONC,MEAN_LEAF_LIGNIN_CONC,SDEV_LEAF_LIGNIN_CONC,
MEAN_LEAF_CELLULOSE_CONC,SDEV_LEAF_CELLULOSE_CONC,MEAN_LEAF_CHLOROPHYL_A_CONC,
SDEV_LEAF_CHLOROPHYL_A_CONC,MEAN_LEAF_CHLOROPHYL_B_CONC,
SDEV_LEAF_CHLOROPHYL_B_CONC,MEAN_LEAF_CHLOROPHYL_TOT_CONC,
SDEV_LEAF_CHLOROPHYL_TOT_CONC,REVISION_DATE,CRTFCN_CODE
'SSA-9JP-AUX02','RSS04-LCH01',25-JUL-94,05-AUG-94,'F5I6P','0',8,1.242,.125,.995,
.11,23.373,1.092,39.646,2.148,.294,.151,1.994,.635,1.7,.556,26-AUG-98,'CPI'
'SSA-9JP-AUX02','RSS04-LCH01',25-JUL-94,05-AUG-94,'F5I6P','1',8,.755,.08,.975,
.142,25.578,.987,33.648,1.293,.395,.191,2.231,.28,1.836,.28,26-AUG-98,'CPI'
```

8. Data Organization

8.1 Data Granularity

The smallest unit of data tracked by BOREAS Information System (BORIS) is all the leaf chemistry data or all the modeled spectra data, including the model code and input files.

8.2 Data Format(s)

The chemistry data files on CD-ROM contain a series of numerical and character fields of varying length separated by commas. The character fields are enclosed within single apostrophe marks. There are no spaces between the fields.

Each data file on the CD-ROM has 4 header lines of HTML code at the top. When viewed with a Web browser, this code displays header information (data set title, location, date, acknowledgements, etc.) and a series of HTML links to associated data files and related data sets. Line 5 of each data file is a list of the column names, and line 6 and following lines contain the actual data.

Two additional files are included with this dataset and pertain to the LIBERTY model input and output, MODELED_SPECTRA.DAT and LIBERTY.ZIP.

Predicted Spectra File: MODELED_SPECTRA.DAT

The file contains numerical and character fields of varying length separated by commas. The file was generated with Macintosh Excel v5.0. The file contains nine header records followed by a series of data records. The nine header records are:

```
Record 1:   Filename, Number of Rows/Columns, PI-Names
Record 2:   Related data sets
Record 3-7: Column names for the data in the file with a brief description
Record 8:   Plot name - data for each plot consist of three columns R, single
            refl, single trans
Record 9:   Column names for the data in the file delimited by commas
```

Compressed within the file LIBERTY.ZIP file are eight files:
liberty.c
libinv.c
lib_user.txt
albino.dat
pigment.dat
water.dat
ligcell.dat
protein.dat

For additional information about the ASCII files extracted from the LIBERTY.ZIP file and how they are used, see the lib_user.txt file (also extracted from the zip file). Zip archive files are compatible with archives created by PKWARE's PKZIP and PKUNZIP for MS-DOS, but in many cases the program options or default behaviors differ. The liberty.zip archive has been tested and extracted on an SGI with IRIS 6.5, a Sun with SunOS 5.7, and a Mac (UnZip and ZipIt). See also, section 9.3.2.

9. Data Manipulations

9.1 Formulae

water(% dry) = (fresh weight - dry weight)/(dry weight)

Chlorophyll-a = 9.93 A660 - 0.777 A642.5
Chlorophyll-b = 17.6 A642.5 - 2.81 A660
Total Chlorophyll = 7.12 A660 + 16.8 A642.5

where A660 and A642.5 refer to absorption at 660 and 642.5 nm, respectively.

The nitrogen, lignin, and cellulose chemistry was derived using partial least- squares regression on the first difference of the spectral measurements. A full discussion of the approach and its comparison against stepwise multiple regression is given in Bolster et al. (1996).

9.1.1 Derivation Techniques and Algorithms

Not applicable.

9.2 Data Processing Sequence

9.2.1 Processing Steps

See Section 5 for preliminary information.

a) Water

The samples were removed from a deep freeze and weighed. Then they were frozen down to -30 °C and placed in a freeze-drier for 2 days. The samples were then reweighed and water content was calculated as a function of the dry mass:

water(% dry) = (fresh weight - dry weight)/(dry weight)

b) Chlorophyll

For chlorophyll analysis, fresh samples were defrosted and then ground in a coffee grinder. Despite the delay between collection and processing, the fresh-cut samples were in excellent condition. Spectral reflectance of all 154 samples was measured using a Spectron S106 laboratory spectrometer. The chlorophyll was determined by wet chemical methods. Forty-six samples were selected by Mahalanobis distance from the mean to represent the spectral variation in the data set prescribed by the first difference of the spectral reflectance.

Chlorophyll determination was conducted following the method of MacKinney (1941) and Lichtenthaler (1987) for three independent measurements per sample, making a total of 138 (46*3) individual values. The chlorophyll from ground freeze-dried samples was extracted in 90% acetone buffered with $CaCO_3$. The concentration of chlorophyll-a and chlorophyll-b in the aliquot was then derived spectrophotometrically using the Spectron S106 calibrated against samples of spinach of known chlorophyll concentration obtained from the Aldrich Chemical Company, UK.

Stepwise regression was conducted using five prediction wavelengths in the 400-750-nm wavelength region to generate a prediction equation for the remaining samples. The correlation coefficients against chlorophyll-a, chlorophyll-b, and total chlorophyll were all greater than 0.92.

Visual examination of the three separate predictions revealed large disparities in only two of the samples. These disparities were attributed to laboratory spectral measurement error and were revised. The resulting relationships were:

Chlorophyll-a = 9.93 A660 - 0.777 A642.5
Chlorophyll-b = 17.6 A642.5 - 2.81 A660
Total Chlorophyll = 7.12 A660 + 16.8 A642.5

where A660 and A642.5 refer to absorption at 660 and 642.5 nm, respectively.

The standard deviation between measurements of the same sample varied between 0.0237 to 0.6338 mg/g, with an average standard deviation of 0.201 mg/g.

c) Nitrogen, Lignin, Cellulose

The concentration of these three chemicals was derived for RSS-04 by UNH (Aber, Bolster, Martin). Ground, freeze-dried samples were dispatched to UNH, where they were reground using a Wiley Mill to increase particle size consistency. The samples were then scanned in an NIRSystems 6500 monochromator with a spinning cup module calibrated using a range of plant species, including Pinus resinosa and Pinus strobus. While jack pine (Pinus banksiana) is not in the calibration set, the predicted values fall well within the concentration ranges of the calibration data set. The chemistry was then derived using partial least-squares regression on the first difference of the spectral measurements. A full discussion of the approach and its comparison against stepwise multiple regression is given in Bolster et al. (1996).

9.2.2 Processing Changes

None.

9.3 Calculations

Estimated infinite reflectance, single-needle reflectance, and transmittance were calculated for each sample plot based on the plot average of measured chemical concentrations of needles. A full description of the LIBERTY model is given in the series of papers by Dawson et al. (see Section 17).

9.3.1 Special Corrections/Adjustments

None, except see Dawson et al. for spectral estimation.

9.3.2 Calculated Variables

- Predicted needle infinite reflectance spectra
- Predicted single needle reflectance and transmittance spectra

LIBERTY is a general-purpose radiative transfer model for predicting the reflectance and transmittance spectra of a leaf, or stack of leaves in the visible and near-infrared wavelengths (400-2500 nm). By treating a leaf as an aggregation of cells, with multiple radiation scattering between cells, output spectra is a function of three structural parameters and the combined absorption coefficients of leaf biochemicals. The user is prompted for input values, and the model output is written to an external file for use with graphing and spreadsheet packages as well as for coupling with vegetation canopy or ecosystem models. It is written in C and, using external absorption coefficient files, has been successfully compiled for the following platforms:

- MS-DOS
- SUN Microsystems Solaris
- Silicon Graphics IRIX

No header or make files are required; all calls to external libraries and function definitions are made at the beginning of the program.

LIBERTY was developed specifically for conifer needles, so the estimation of single leaf reflectance and transmittance spectra from stacked needles is possible. However, the program is equally valid for any leaf species with a minor caveat; the in-vivo absorption coefficients used were determined from empirical work on various pine species.

LIBERTY uses external data files. This allows the user to easily modify the existing absorption coefficients or provide new ones. The required file list is:

```
PIGMENT.DAT    Absorption coefficient of in-vivo chlorophylls and carotenoids
ALBINO.DAT     Absorption coefficient of dried albino leaf due to lignin
               (visible wavelengths)
WATER.DAT      Water absorption coefficient
LIGCELL.DAT    Combined absorption coefficient of lignin and cellulose
PROTEIN.DAT    Protein absorption coefficient
```

The following inputs are required from the user:

Variable	Description	Typical values (range)
Cell Diameter	Average leaf cell diameter ($1/m^6$)	40 (20-100)
Intercellular Determinant for the amount of air space	radiative flux passing between cells	0.045 (0.01-0.1)
Leaf thickness	Arbitrary value to determine single leaf reflectance and transmittance from infinite reflectance criteria	1.6 (1-10)
Baseline Wavelength	compensate for changes in absolute reflectance independent absorption to absorption	Fresh: 0.0006 Dry: 0.0004
Albino	Absorption in the visible region due to lignin absorption	2 (0-4)
Chlorophyll content	Chlorophyll (pigment) content (mg/m^2)	200 (0-600)
Water content	Water content (g/m^2)	100 (0-500)
Lignin and Cellulose content	Combined lignin and cellulose content (g/m^2)	40 (10-80)
Nitrogen content	Nitrogen content (g/m^2)	1 (0.3-2.0)

9.4 Graphs and Plots

None given.

10. Errors

10.1 Sources of Error

Some error should be expected as a function of the delay in transferring samples from each site back to the UK. While every effort was made to limit this effect (sealed bags, refrigeration, darkness, CO_2), the facilities/manpower were not available for onsite processing, particularly given the 'alternative-fund status' of RSS-04 involvement.

10.2 Quality Assessment

10.2.1 Data Validation by Source

For a discussion of the accuracy of estimates of nitrogen, lignin and cellulose, please see Bolster et al. (1996) and reports to the NERC and National Aeronautics and Space Administration (NASA) Accelerated Canopy Chemistry Program (ACCP) by Curran, Kupiec and Smith (1994). Similarly, for a full discussion of the LIBERTY model and the assumptions of the model, please see the Dawson et al. series of papers.

10.2.2 Confidence Level/Accuracy Judgment

None given.

10.2.3 Measurement Error for Parameters

None given.

10.2.4 Additional Quality Assessments

None given.

10.2.5 Data Verification by Data Center

BOREAS staff has reviewed submitted data files, formats, and documentation for general consistency and content.

11. Notes

11.1 Limitations of the Data

None given.

11.2 Known Problems with the Data

None given.

11.3 Usage Guidance

None given.

11.4 Other Relevant Information

None given.

12. Application of the Data Set

None given.

13. Future Modifications and Plans

None given.

14. Software

14.1 Software Description

Version 1.1 LIBERTY leaf reflectance and transmittance model. LIBERTY is a general-purpose radiative transfer model for predicting the reflectance and transmittance spectra of a leaf, or stack of leaves, in the visible and infrared wavelengths (400-2500 nm). By treating a leaf as an aggregation of cells, with multiple radiation scattering between cells, output spectra is a function of three structural parameters and the combined absorption coefficients of leaf biochemicals. The user is prompted for input values, and the model output is written to an external file for use with graphing and spreadsheet packages as well as for coupling with vegetation canopy or ecosystem models. It is written in C and, using external absorption coefficient files, has been successfully compiled for the following platforms:

- MS-DOS
- SUN Microsystems Solaris
- Silicon Graphics IRIX

14.2 Software Access

Anyone wishing to register an interest in receiving updates to the LIBERTY code should contact Stephen Plummer at the e-mail address given in Section 2.3. See additional information regarding the LIBERTY model in Section 9.3.2.

15. Data Access

The RSS-04 leaf chemistry and spectral data are available from the Earth Observing System Data and Information system (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

ORNL DAAC User Services
Oak Ridge National Laboratory
P.O. Box 2008 MS-6407
Oak Ridge, TN 37831-6407
Phone: (423) 241-3952
Fax: (423) 574-4665
E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/.

15.3 Procedures for Obtaining Data

Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products

None.

16.2 Film Products

None.

16.3 Other Products

American Standard Code for Information Interchange (ASCII) files containing leaf chemistry data and the LIBERTY output file produced by RSS-04, the source code for LIBERTY, updates to the model can be obtained from Dr. Stephen Plummer (see Section 2.3).

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

Not applicable.

17.2 Journal Articles and Study Reports

Bolster, K.L., M.E. Martin, and J.D. Aber, 1996. Determination of carbon fraction and nitrogen concentration in tree foliage by near-infrared reflectance - A comparison of statistical methods. Can. J. Forest. Res. 26,590-600.

Curran, P.J. and J.A. Kupiec. 1994. The remote sensing of foliar chemistry Final Report to the Natural Environment Research Council. March 1994.

Dawson, T.P., P.J. Curran, and S.E. Plummer. 1995. Modelling the spectral response of coniferous leaf structures for the estimation of biochemical concentrations. RSS'95. Rem. Sens. Soc. Nottingham, UK. 587-594.

Dawson, T.P., P.J. Curran, and S.E. Plummer. 1996. A model approach to the biochemical analysis of coniferous forests from AVIRIS data. Proc. Second Int. Airborne Rem. Sens. Conf. ERIM. Ann Arbor, MI. Vol. I, 221-227.

Dawson, T.P., Curran, P.J. and Plummer, S.E., 1996, LIBERTY - Towards the estimation of foliar biochemical concentration using high spectral resolution airborne sensors, RSS'96, Rem. Sens. Soc., Nottingham, UK, 79-86.

Dawson, T.P., P.J. Curran, and S.E. Plummer. 1997. LIBERTY - modelling the effects of leaf biochemistry on reflectance spectra. Rem. Sens. Env. (in press).

Hosgood, B., S. Jacquemoud, G. Andreoli, J. Verdebout, G. Pedrini, and G. Schmuck. 1995. Leaf optical properties experiment 93 (LOPEX93). Joint Research Centre European Commission publication no. EUR 16095 EN, Luxembourg.

Kupiec, J.A. and P.J. Curran. 1994. The chemical and spectral variability in a slash pine canopy. Final Report to NASA Accelerated Canopy Chemistry (New Observations) Program. UNH Subcontract 93-20, Vol II.

Lichtenthaler, H.K. 1987. Chlorophylls and caroteinoids: pigments of photosynthetic biomembranes. Methods in Enzymology. 148, 350-382.

Mackinney, G. 1941. Absorption of light by chlorophyll solutions. J. Biol. Chem. 140, 315-322.

North, P.R. 1996. A three-dimensional forest light interaction model using a Monte-Carlo method. IEEE Trans. Geosci. and Rem. Sens. 34, 946-956.

North, P.R. and S.E. Plummer. 1994. Estimation of conifer bi-directional reflectance using a Monte Carlo method. IGARSS'94, IEEE. Piscataway, NJ. Vol. I, 114-116.

North, P.R., S.E. Plummer, D.W. Deering, and Leroy, M. 1996. Validation of a BRDF model for boreal forest. IGARSS'96, IEEE. Piscataway, NJ. Vol.III, X, 1654-1656.

Sellers P.J, and F.G. Hall. 1994. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1994-3.0 NASA BOREAS Report (EXPLAN 94).

Sellers P.J., F.G. Hall, H. Margolis, B. Kelly ,D. Baldocchi ,G. den Hartog, J. Cihlar, M.G. Ryan, B. Goodison, P. Crill, K.J. Ranson, D. Lettenmaier, and D.E. Wickland. 1995. The boreal ecosystem-atmosphere study (BOREAS): an overview and early results from the 1994 field year. Bulletin of the American Meteorological Society, 76, 1549-1577.

Sellers P.J., F.G. Hall, and K.F. Huemmrich. 1996. Boreal Ecosystem-Atmosphere Study: 1994 Operations. NASA BOREAS Report (OPS DOC 94).

Sellers P.J., and F.G. Hall. 1996. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1996-2.0 NASA BOREAS Report (EXPLAN 96).

Sellers P.J., F.G. Hall, and K.F. Huemmrich. 1997. Boreal Ecosystem-Atmosphere Study: 1996 Operations. NASA BOREAS Report (OPS DOC 96).

Sellers, P.J., F.G. Hall, R.D. Kelly, A. Black, D. Baldocchi, J. Berry, M. Ryan, K.J. Ranson, P.M. Crill, D.P. Lettenmaier, H. Margolis, J. Cihlar, J. Newcomer, D. Fitzjarrald, P.G. Jarvis, S.T. Gower, D. Halliwell, D. Williams, B. Goodison, D.E. Wickland, and F.E. Guertin. (1997). "BOREAS in 1997: Experiment Overview, Scientific Results and Future Directions", Journal of Geophysical Research (JGR), BOREAS Special Issue, 102(D24), Dec. 1997, pp. 28731-28770.

17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None given.

19. List of Acronyms

ACCP - Accelerated Canopy Chemistry Program
ASCII - American Standard Code For Information Interchange
AVIRIS - Airborne Visible and InfraRed Imaging Spectrometer
BGC - Biogeochemistry
BNSC - British National Space Centre
BOREAS - BOReal Ecosystem Atmosphere Study
BORIS - BOREAS Information System
DAAC - Distributed Active Archive Center
EOS - Earth Observing System
EOSDIS - EOS Data and Information System
FAA - Federal Aviation Administration
fPAR - Fraction of absorbed Photosynthetically Active Radiation
GMT - Greenwich Mean Time
GSFC - Goddard Space Flight Center
IFC - Intensive Field Campaign
ITE - Institute of Terrestrial Ecology
LAI - Leaf Area Index
LIBERTY - Leaf Incorporating Biochemistry Exhibiting Reflectance and Transmittance Yields
NAD83 - znorth American Datum of 1983
NASA - National Aeronautics and Space Administration
NERC - Natural Environment Research Council (UK)
NSA - Northern Study Area
OBS - Old Black Spruce
OJP - Old Jack Pine
ORNL - Oak Ridge National Laboratory
PANP - Prince Albert Nationa Park
PAR - Photosynthetically Active Radiation
PARABOLA - Portable Apparatus for Rapid Acquisition of Bidirectional Observations of Land and Atmosphere
PI - Principal Investigator
POLDER - Polarization and Directionality of Earth Rdiance
RSADU - Remote Sensing Applications Development Unit
RSS - Remote Sensing Science
SSA - Southern Study Area
UMSP - Universal Microspectrophotometer
UNH - University of New Hampshire
URL - Uniform Resource Locator
UTM - Universal Transverse Mercator
WAB - Wind-Aligned Blob
YJP - Young Jack Pine

20. Document Information

20.1 Document Revision Date

Written: 07-Jan-1997
Last updated: 14-Sep-1998

20.2 Document Review Date(s)

BORIS Review: 09-Sep-1998
Science Review: 15-Jul-1998

20.3 Document ID

20.4 Citation

When using these data, please include the following acknowledgment as well as citations of relevant papers in Section 17.2:

Data: Leaf chemistry data were gathered by Dr. Stephen Plummer (Institute of Terrestrial Ecology) and Dr. Neil Lucas (University of Kingston) and processed at the Universities of Southampton and New Hampshire under the direction of Terry Dawson (University of Southampton).

Model Spectra: The LIBERTY model and associated spectra were generated as part of a doctoral study by Mr. Terry Dawson (University of Southampton).

If using data from the BOREAS CD-ROM series, also reference the data as:

Plummer., S., N. Lucas, and T. Dawson, "Jack Pine Leaf Biochemistry and Modeled Spectra in the SSA." In Collected Data of The Boreal Ecosystem-Atmosphere Study. Eds. J. Newcomer, D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers. CD-ROM. NASA, 2000.

Also, cite the BOREAS CD-ROM set as:

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM. NASA, 2000.

20.5 Document Curator

20.6 Document URL

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	July 2000	Technical Memorandum

4. TITLE AND SUBTITLE
Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)
BOREAS RSS-4 1994 Jack Pine Leaf Biochemistry and Modeled Spectra in the SSA

5. FUNDING NUMBERS
923
RTOP: 923-462-33-01

6. AUTHOR(S)
Stephen Plummer, Neil Lucas, and Terry Dawson
Forrest G. Hall and Jaime Nickeson, Editors

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS (ES)
Goddard Space Flight Center
Greenbelt, Maryland 20771

8. PEFORMING ORGANIZATION REPORT NUMBER
2000-03136-0

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS (ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
TM—2000–209891
Vol. 50

11. SUPPLEMENTARY NOTES
S. Plummer: Institute of Terrestrial Ecology; N. Lucas: University of Kingston;
T. Dawson: University of Southampton; J. Nickeson: Raytheon ITSS

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Unclassified–Unlimited
Subject Category: 43
Report available from the NASA Center for AeroSpace Information,
7121 Standard Drive, Hanover, MD 21076-1320. (301) 621-0390.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The BOREAS RSS-4 team focused its efforts on deriving estimates of LAI and leaf chlorophyll and nitrogen concentrations from remotely sensed data for input into the Forest BGC model. This data set contains measurements of jack pine (Pinus banksiana) needle biochemistry from the BOREAS SSA in July and August 1994. The data contain measurements of current and year-1 needle chlorophyll, nitrogen, lignin, cellulose, and water content for the OJP flux tower and nearby auxiliary sites. The data have been used to test a needle reflectance and transmittance model, LIBERTY (Dawson et al., in press). The source code for the model and modeled needle spectra for each of the sampled tower and auxiliary sites are provided as part of this data set. The LIBERTY model was developed and the predicted spectral data generated to parameterize a canopy reflectance model (North, 1996) for comparison with AVIRIS, POLDER, and PARABOLA data. The data and model source code are stored in ASCII files.

14. SUBJECT TERMS	15. NUMBER OF PAGES
BOREAS, remote sensing science, LIBERTY.	25
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL